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(72) Inventors:
• **Matthews, Kim Nigel**
Watchung, New Jersey 07060 (US)
• **Matthews, Elissa P.**
Watchung, New Jersey 07060 (US)

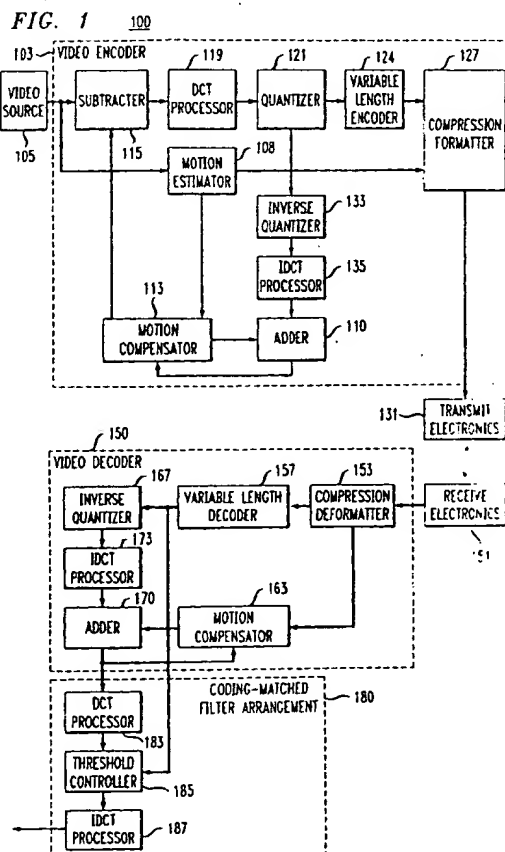
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(74) Representative:
Watts, Christopher Malcolm Kelway, Dr. et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green Essex, IG8 0TU (GB)

(71) Applicant: **Lucent Technologies Inc.**
Murray Hill, New Jersey 07974-0636 (US)

(54) Technique for video communications using a coding-matched filter arrangement

(57) In a system for communicating an image, an image compression scheme is employed to encode the image to reduce the required bandwidth for transmitting same. For example, this compression scheme includes performing, on the image, a discrete cosine transform (DCT), followed by quantization. To reduce the effects of coding artifacts occasioned by the compression scheme, in accordance with the invention, a filter arrangement which is matched to the coding of the image may be utilized to process a received image. The filter arrangement is designed to truncate each non-zero frequency component in the received image whose amplitude is lower than a certain threshold, which is a function of the quantization step size used.

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Description

Field of the Invention

[0001] The invention relates to communications systems and methods, and more particularly to a system and method for video communications which implements an image compression scheme.

Background of the Invention

[0002] In video communications, images are coded in accordance with an image compression scheme to reduce the required bandwidth for transmitting the images. In accordance with such well known image compression standards as the MPEG, MPEG-2, motion-JPEG and JPEG standards, an image coding process typically includes performing a block based frequency transform, e.g., discrete cosine transform (DCT), on an image to be transmitted. The resulting DCT coefficients are quantized or mapped to different quantization steps to render an approximate representation thereof. If the available transmission bandwidth is relatively small, with respect to the complexity of the image to be transmitted, the size of the quantization steps needs to be relatively large. In that case, the resulting coarse quantization of the DCT coefficients introduces coding artifacts into the transmitted image, which include, e.g., speckle-like distortions near edges of objects appearing in a recovered image.

[0003] Attempts have been made to reduce effects of the coding artifacts by postprocessing the recovered image. Since the artifacts typically comprise high frequency components, such attempts invariably involve use of a postprocessor including a low-pass filter to filter out those components in the recovered image. However, the design of such a postprocessor is normally determined by experiment in an ad hoc manner. As a result, the quality of the postprocessed image is highly dependent upon how close the actual types of image transmitted and transmission rates used in the field are to those in the experiment. Consequently, use of the prior art postprocessor to improve the image quality is, at best, precarious as the performance achieved thereby may drastically vary from one set of field conditions to another.

[0004] Accordingly, there exists a need for a dependable technique for effectively reducing the effects of the coding artifacts in an image subject to an image coding process.

Summary of the Invention

[0005] We have recognized that due to the implementation of the above image coding process, which involves quantization of block based frequency transform coefficients, e.g., DCT coefficients, concerning a transmitted image, the amplitude of each non-zero frequency component of the image, when received, cannot be

smaller than a threshold value, which is a function of the quantization step size. That is, any non-zero frequency component having an amplitude smaller than the threshold value must be erroneously created, perhaps, by aliasing which is incurred due to the block structure of the transform coefficients traversing a channel, which is band limited.

[0006] Thus, in accordance with the invention, using a filter arrangement which is matched to the coding of the image involving the above quantization, the received image is transformed into a set of frequency components representative thereof. The quantization step size used in the quantization may vary from frequency component to frequency component. Each frequency component having a value below a threshold value corresponding thereto is removed from the set, where the threshold value is a function of the quantization step size associated with the frequency component. Advantageously, the resulting image formed by the remaining frequency components is superior in quality to the received image, with the effects of the coding artifacts in the received image substantially reduced. In addition, the effectiveness of the inventive technique is independent of the field conditions under which the image is communicated.

Brief Description of the Drawing

[0007] In the drawing,

Fig. 1 is a block diagram of a communications system in accordance with the invention for communicating video images;

Fig. 2 illustrates a postprocess performed by a coding-matched filter arrangement in accordance with the invention to improve the quality of a recovered image in the system of Fig. 1; and

Fig. 3 illustrates a video encoder using the coding-matched filter arrangement as a preprocessor in accordance with the invention.

Throughout this disclosure, unless otherwise stated, like elements, components or sections in the figures are denoted by the same numeral.

Detailed Description

[0008] Fig. 1 illustrates communications system 100 embodying the principles of the invention for communicating video images. As shown in Fig. 1, system 100 comprises video source 105, video encoder 103, transmit electronics 131, receive electronics 151 and video decoder 150, all of conventional design, and coding-matched filter arrangement 180 in accordance with the invention.

[0009] Video source 105 in a conventional manner

provides a bit stream representing images on a frame by frame basis. Each frame comprises $L \times M$ pixels, where L and M are selected integers greater than zero. For example, $L = 720$ and $M = 480$ in this instance. In response to such a bit stream, motion estimator 108, in a standard way, derives motion vectors indicating differences between the current image frame and the previous image frame from source 105. Based on such motion vector information, and the previously transmitted frame provided by adder 110 to be described, motion compensator 113 generates a predicted version of the current frame to be transmitted. This predicted version is provided to adder 110 and subtracter 115. The latter subtracts the predicted version of the current frame from the original version thereof from source 105, thereby forming a prediction error signal.

[0010] Discrete cosine transform (DCT) processor 119 performs a well known DCT, which is a block based frequency transform, on the prediction error signal from subtracter 115. The resulting DCT coefficients are arranged two-dimensionally in blocks. These DCT coefficients are quantized by quantizer 121, entropy encoded by variable length encoder 124, and formatted by compression formatter 127, in accordance with the well known MPEG image compression scheme described in: D. LeGall, "MPEG, a Video Compression for Multimedia Applications," *Transactions of ACM*, vol. 34, no. 4, April 1991, pp. 46-58. To properly carry out such an image compression scheme, the aforementioned motion vector information is also provided by estimator 108 to compression formatter 127.

[0011] It should be noted at this point that although quantizer 121 is a linear quantizer, the quantization step size used therein varies with the position of each DCT coefficient in a block to control the resulting quantization error corrupting the frequency component represented thereby. Thus, the quantization step size here is generically represented by Q_{ij} , where i and j represent the row and column indexes of the DCT coefficient corresponding thereto in a block. It should also be noted that each Q_{ij} varies from block to block and, thus, with time.

[0012] Specifically, the value of each DCT coefficient input to quantizer 121 is divided by the corresponding Q_{ij} , thereby obtaining a quotient qt which may be zero, and a remainder R which may also be zero. R is then compared with a "quantization threshold" which is $Q_{ij}/2$ in this example. If $R \geq Q_{ij}/2$, the signal assumes a level of $(qt + 1)Q_{ij}$ for the coding purposes. Otherwise if $R < Q_{ij}/2$, the signal assumes a level of $(qt)Q_{ij}$.

[0013] The information concerning the quantization step size Q_{ij} is also provided to variable length encoder 124 for transmission to video decoder 150. The output of compression formatter 127 may range from 1 Mb/s to 20 Mb/s, and is transmitted by transmit electronics through a communication channel.

[0014] The quantized DCT coefficients from quantizer 121 are fed back to inverse quantizer 133 to reconstruct the transmitted frame ultimately recovered in decoder

150. To that end, inverse quantizer 133 de-quantizes the quantized DCT coefficients, and thereby provides an approximate version of the original DCT coefficients. Based on such an approximate version, inverse DCT (IDCT) processor 135 recovers the prediction error signal. Adder 110 adds the recovered prediction error signal to the aforementioned predicted version of the transmitted frame from compensator 113, thereby reconstructing the transmitted frame, which is used by compensator 113 to predict the upcoming transmitted frame in a manner described before.

[0015] Receive electronics 151 receives, through the aforementioned communication channel, a signal representative of a transmitted image frame from transmit electronics 131. The received signal is processed by compression deformatter 153 in video decoder 150. Deformatter 153 performs the inverse function to compression formatter 127 described before. Among other things, deformatter 127 recovers the aforementioned motion vector information, which is fed to motion compensator 163. The remaining output is further processed by variable length decoder 157 which performs the inverse function to variable length encoder 124 described before. The output of decoder 157, which consists of the quantization step size information and quantized DCT coefficients, is provided to inverse quantizer 167. Where in some instances video encoder 103 may also provide field/frame information concerning the transmitted frame, the output of decoder 157 would also consist of such information. The quantization step size information, along with any field/frame information, is provided to coding-matched filter arrangement 180 described below.

[0016] It should be noted at this point that motion compensator 163, inverse quantizer 167, IDCT processor 173 and adder 170 in receiver 150 operate similarly to motion compensator 113, inverse quantizer 133, IDCT processor 135 and adder 110 in transmitter 103 to reconstruct the transmitted frame. Thus, based on the received motion vector information, like compensator 113, compensator 163 provides a predicted version of the transmitted frame to adder 170. Based on the quantized DCT coefficients and the received quantization step size, like inverse quantizer 133, inverse quantizer 167 provides a de-quantized, approximate version of the coefficients. Based on such an approximate version, like IDCT processor 135, IDCT processor 173 recovers the prediction error signal. Adder 170 adds the prediction error signal to the predicted version of the transmitted frame from compensator 163 to recover the transmitted frame. The recovered frame is fed back to compensator 163 to provide the predicted version of the upcoming transmitted frame.

[0017] However, the recovered image frame from adder 170 is corrupted by coding artifacts resulting from the MPEG coding scheme used in video encoder 103. These artifacts are attributable to the DCT, followed by the quantization in such a scheme. Specifically, in trans-

mitter 103, the prediction error signal from subtracter 115 is DCT transformed by processor 119 and then quantized by quantizer 121. If the values of the DCT coefficients from processor 119 are relatively small and the quantization step size is relatively large to effectively reduce the transmission rate, the coefficients may all be quantized to zero. This leads to transmission of a zero prediction error signal to receiver 150. As a result, the predicted version of the transmitted frame from motion compensator 163 in receiver 150 would not be corrected, thereby causing "prediction coding" artifacts. In addition, by virtue of use of the DCT which is a block based frequency transform, well known "block" artifacts also emerge in the recovered image frame.

[0018] In accordance with the invention, the recovered image frame from adder 170 is further processed by coding-matched filter arrangement 180 to reduce the effects of the aforementioned artifacts. Filter arrangement 180 is designed based on the coding scheme used, and in this instance is matched to that of the aforementioned MPEG scheme involving the DCT and quantization. Specifically, the recovered image frame from adder 170 is processed by DCT processor 183 in arrangement 180. Processor 183 in this instance performs a well known 8 x 8 DCT on the recovered image frame. However, it will be appreciated that a person skilled in the art may opt to perform other transforms, although less preferable, such as the Walsh-Hadamard transform or a one-dimensional transform, instead.

[0019] In performing the 8 x 8 DCT, processor 183 first divides the recovered image frame into blocks of 8 pixels by 8 pixels. Each block is associated with one or more pixels in the frame. Fig. 2 illustrates one such block denoted 205 which includes pixels A1, B1, ..., and H8, and is associated with pixel D4 only. Processor 183 then transforms each block in accordance with the DCT. For example, the transformed version of block 205 is illustratively block 207, which includes DCT coefficients a1, b1, ..., and h8 corresponding thereto.

[0020] We have recognized that because of the implementation of the aforementioned coding scheme involving the quantized DCT transformation in encoder 103, the smallest value of a nonzero DCT coefficient in block 207 cannot be smaller than the corresponding quantization threshold $Q_{ij}/2$. Any non-zero DCT coefficient in block 207 having an absolute value smaller than the corresponding $Q_{ij}/2$ must be erroneously created, perhaps, by aliasing which is incurred due to the block structure of the DCT coefficients from DCT processor 119 traversing the aforementioned communication channel, which is band limited.

[0021] Thus, in accordance with the invention, in response to the aforementioned information concerning Q_{ij} from video decoder 150, threshold controller 185 truncates all DCT coefficients whose absolute values are below the corresponding $Q_{ij}/2$ to zero, without losing any transmitted information. Assuming that all DCT coefficients in block 207, except a few coefficients, namely,

a1, b1, c1, d1, e1, a2, b2, c2, d2, a3, b3 and a4, each have an absolute value smaller than the corresponding $Q_{ij}/2$, controller 185 accordingly replaces all the DCT coefficients except those few coefficients with a zero, thereby yielding block 209. IDCT processor 187 then performs an inverse DCT on block 209, resulting in block 211 consisting of pixels A1', B1', ..., and H8'. However, the output of processor 187 in this instance consists of pixel D4' in block 211 corresponding to pixel D4 associated with block 205. This output replaces pixel D4 in the recovered frame from decoder 150. The process of Fig. 2 is similarly repeated for each other block as divided by processor 183 for replacement of the pixel associated therewith. The resulting frame containing the replacement pixels is advantageously superior in quality to the recovered frame, with the effects of the aforementioned coding artifacts substantially reduced.

[0022] The foregoing merely illustrates the principles of the invention. It will thus be appreciated that a person skilled in the art will be able to devise numerous arrangements which, although not explicitly shown or described herein, embody the invention.

[0023] For example, in the disclosed embodiment, coding-matched filter arrangement 180 in accordance with the invention is used as a postprocessor in communication system 100. However, it will be appreciated that the inventive arrangement may be used as a preprocessor in the system as well. Fig. 3 illustrates one such system wherein coding-matched filter arrangement 380 similar to arrangement 180 processes the bit stream representative of image frames from video source 105 before video encoder 103. In that system, the threshold controller in arrangement 380 effectively removes all frequency components of each image frame whose amplitude is lower than the corresponding threshold $Q_{ij}/2$. It should be noted that the majority of the frequency components in the image frame having such a low amplitude typically are those of high frequencies. The removal of the high frequency information which often represents, e.g., sharp object boundaries, does not significantly affect the image frame visually as human eyes naturally possess particular visual sensitivity toward edges and boundaries in an image anyway. Transmission of the image frames preprocessed by arrangement 380 advantageously requires less bandwidth than their unprocessed counterparts, thereby allowing a finer quantization used in encoder 103 to further reduce the effects of the coding artifacts. Quantization step size controller 303 determines the value Q_{ij} for the threshold controller in arrangement 380 and the quantizer in encoder 103 according to the bit rate allowed by the available transmission bandwidth, where Q_{ij} varies inversely with such a bit rate.

[0024] In addition, although the inventive coding-matched filter arrangement is used with an MPEG coding scheme in the disclosed embodiment, the arrangement may also be matched to, and used with, other image coding schemes such as the MPEG-2 scheme, mo-

tion-JPEG scheme, JPEG scheme, etc.

[0025] Finally, communications system 100 is disclosed herein in a form in which various transmitter functions are performed by discrete functional blocks. However, any one or more of these functions could equally well be embodied in an arrangement in which the functions of any one or more of those blocks or indeed, all of the functions thereof, are realized, for example, by one or more appropriately programmed processors.

Claims

1. A method for processing an image, the image being encoded by a coding process, which includes quantization of information concerning the image in accordance with at least one quantization step size, the method comprising:

transforming the image into a set of components representative thereof, each of the at least one quantization step size being associated with a respective one of the components; and

removing selected ones of the components from the set, each selected component having an absolute value below a threshold value corresponding thereto, the threshold value being a function of the quantization step size associated with the selected component.

2. The method of claim 1 wherein the image is encoded in accordance with an MPEG scheme.
3. The method of claim 1 wherein the image is transformed in accordance with a block based frequency transform.
4. The method of claim 3 wherein the block based frequency transform includes a DCT.
5. A method for processing at least one image for transmission, the image being represented by a selected set of frequency components, the method comprising:

modifying the image, the modified image being represented by a second set of frequency components, each frequency component in the second set being included in the selected set; and quantizing selected information concerning the modified image in accordance with at least one quantization step size, each of the at least one quantization step size being associated with a respective one of the frequency components in the second set, each non-zero frequency component in the second set having an absolute value equal to at least a threshold value corre-

sponding thereto, which is a function of the quantization step size associated with the non-zero frequency component.

6. The method of claim 5 wherein the selected information includes prediction error information indicating a difference between the modified image and a predicted version thereof.
7. The method of claim 6 wherein the prediction error information includes DCT coefficients representative thereof.
8. The method of any of the preceding claims wherein the quantizing is linear.
9. The method of any of the preceding claims wherein the at least one quantization step size varies with time.
10. The method of any of the preceding claims wherein the threshold value equals a half of the associated quantization step size.
11. A method for receiving information concerning at least one image, the method comprising:
 - recovering the image;
 - de-quantizing at least part of the received information in accordance with at least one quantization step size; and
 - modifying the recovered image by removing therefrom selected frequency components of the recovered image, each selected frequency component being associated with a respective one of the at least one quantization step size, each selected frequency component having an absolute value below a threshold value corresponding thereto, the threshold value being a function of the quantization step size associated with the selected frequency component.
12. The method of claim 11 wherein the at least part of the received information includes prediction error information indicating a difference between the image and a predicted version thereof.
13. The method of claim 11 wherein the selected frequency components are represented by DCT coefficients.
14. The method of claim 11 wherein the recovered image includes a plurality of pixels, the method further comprising dividing the recovered image into a plurality of blocks, each block containing a predetermined number of pixels.
15. The method of claim 14 wherein each block is as-

sociated with one or more of the pixels in the block.

16. The method of claim 15 further comprising processing each block to generate one or more pixels to replace the one or more of the pixels associated with the block, respectively. 5
17. The method of claim 16 wherein the one or more pixels generated constitute the modified recovered image. 10
18. Apparatus comprising means arranged to carry out a method as claimed in any of the preceding claims.
19. A computer program product directly loadable into the internal memory of a digital computer comprising software code for performing a method as claimed in any of claims 1 to 17 when said product is run on a computer. 15
20. A computer program product stored on a computer usable medium, comprising computer readable program means for causing a computer to perform a method as claimed in any of claims 1 to 17. 20

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FIG. 1

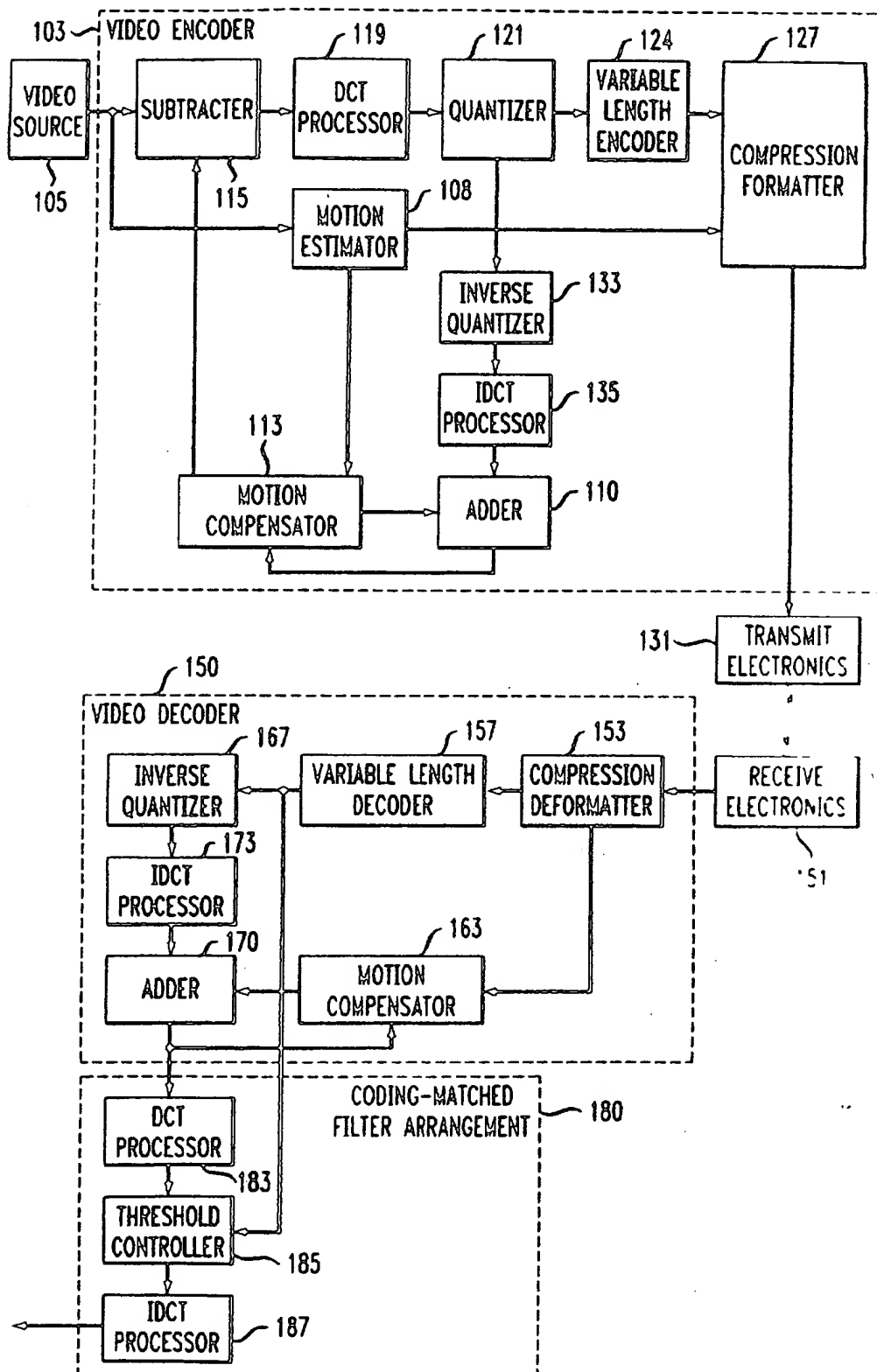


FIG. 2

A1	B1	C1	D1	E1	F1	G1	H1
A2	B2	C2	D2	E2	F2	G2	H2
A3	B3	C3	D3	E3	F3	G3	H3
A4	B4	C4	D4	E4	F4	G4	H4
A5	B5	C5	D5	E5	F5	G5	H5
A6	B6	C6	D6	E6	F6	G6	H6
A7	B7	C7	D7	E7	F7	G7	H7
A8	B8	C8	D8	E8	F8	G8	H8

205

a1	b1	c1	d1	e1	f1	g1	h1
a2	b2	c2	d2	e2	f2	g2	h2
a3	b3	c3	d3	e3	f3	g3	h3
a4	b4	c4	d4	e4	f4	g4	h4
a5	b5	c5	d5	e5	f5	g5	h5
a6	b6	c6	d6	e6	f6	g6	h6
a7	b7	c7	d7	e7	f7	g7	h7
a8	b8	c8	d8	e8	f8	g8	h8

207

a1	b1	c1	d1	e1	0	0	0
a2	b2	c2	d2	0	0	0	0
a3	b3	0	0	0	0	0	0
a4	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

209

A1'	B1'	C1'	D1'	E1'	F1'	G1'	H1'
A2'	B2'	C2'	D2'	E2'	F2'	G2'	H2'
A3'	B3'	C3'	D3'	E3'	F3'	G3'	H3'
A4'	B4'	C4'	D4'	E4'	F4'	G4'	H4'
A5'	B5'	C5'	D5'	E5'	F5'	G5'	H5'
A6'	B6'	C6'	D6'	E6'	F6'	G6'	H6'
A7'	B7'	C7'	D7'	E7'	F7'	G7'	H7'
A8'	B8'	C8'	D8'	E8'	F8'	G8'	H8'

211

FIG. 3